

# **Natural Gas Storage Experience and CO<sub>2</sub> Sequestration**

## **> Third Annual Conference On Carbon Sequestration**

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# Study Objective & Sponsors

- > **Determine What Gas Storage Technology has Been Developed**
  - Define Application to Geologic CO<sub>2</sub> Sequestration.
- > **Study Sponsored by:**
  - > CO<sub>2</sub> Capture Project (CCP)
  - > Klimatek Nor-Cap
  - > Statoil

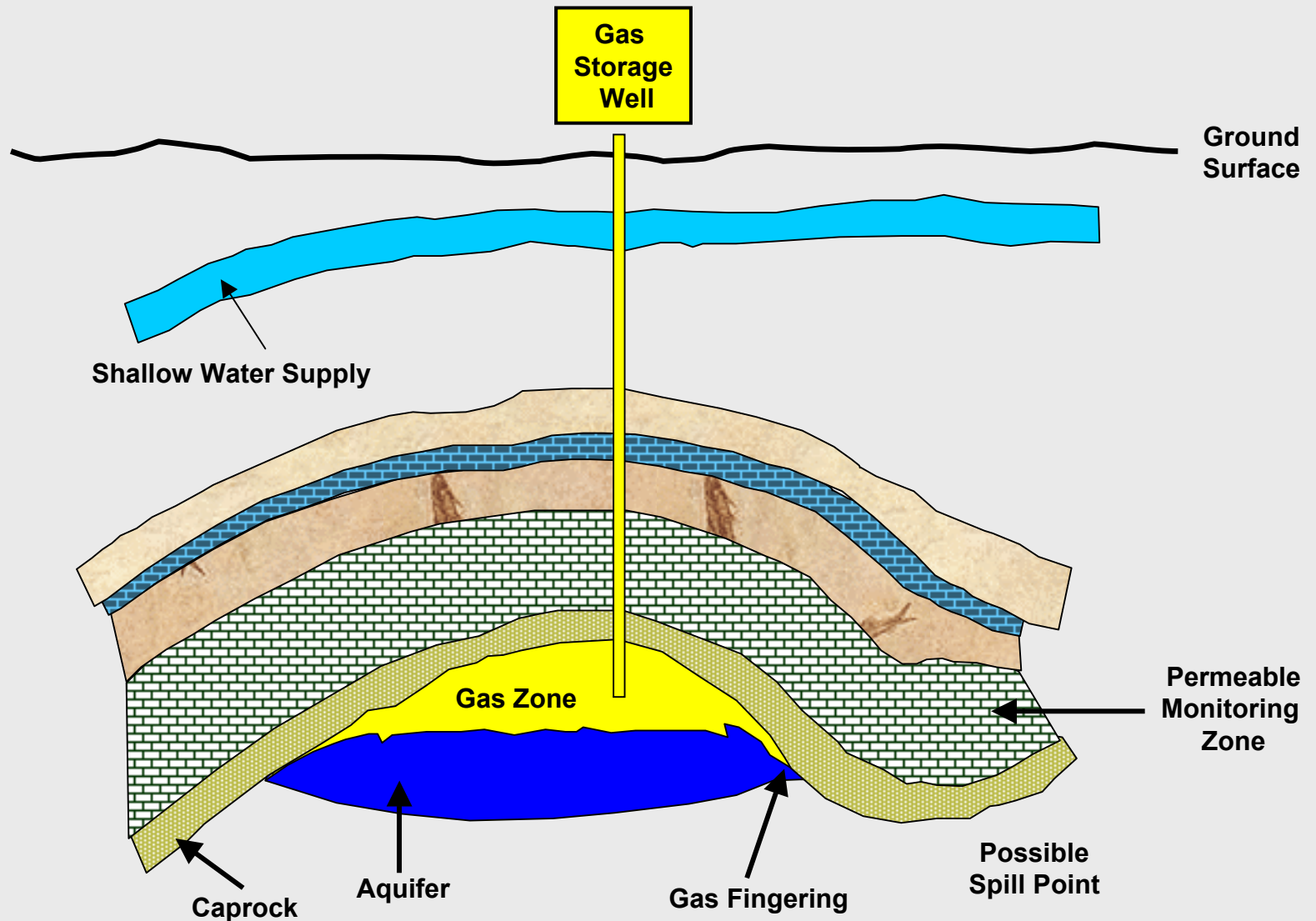
CO<sub>2</sub> Capture Project



# Process

- > Literature Search
- > Interview U.S. Operators
- > Survey of European Operators
  - 17 Countries
- > Focus on:
  - Leaks and Leak Mitigation
  - Field Monitoring
  - Caprock Integrity

# Storage System Definitions



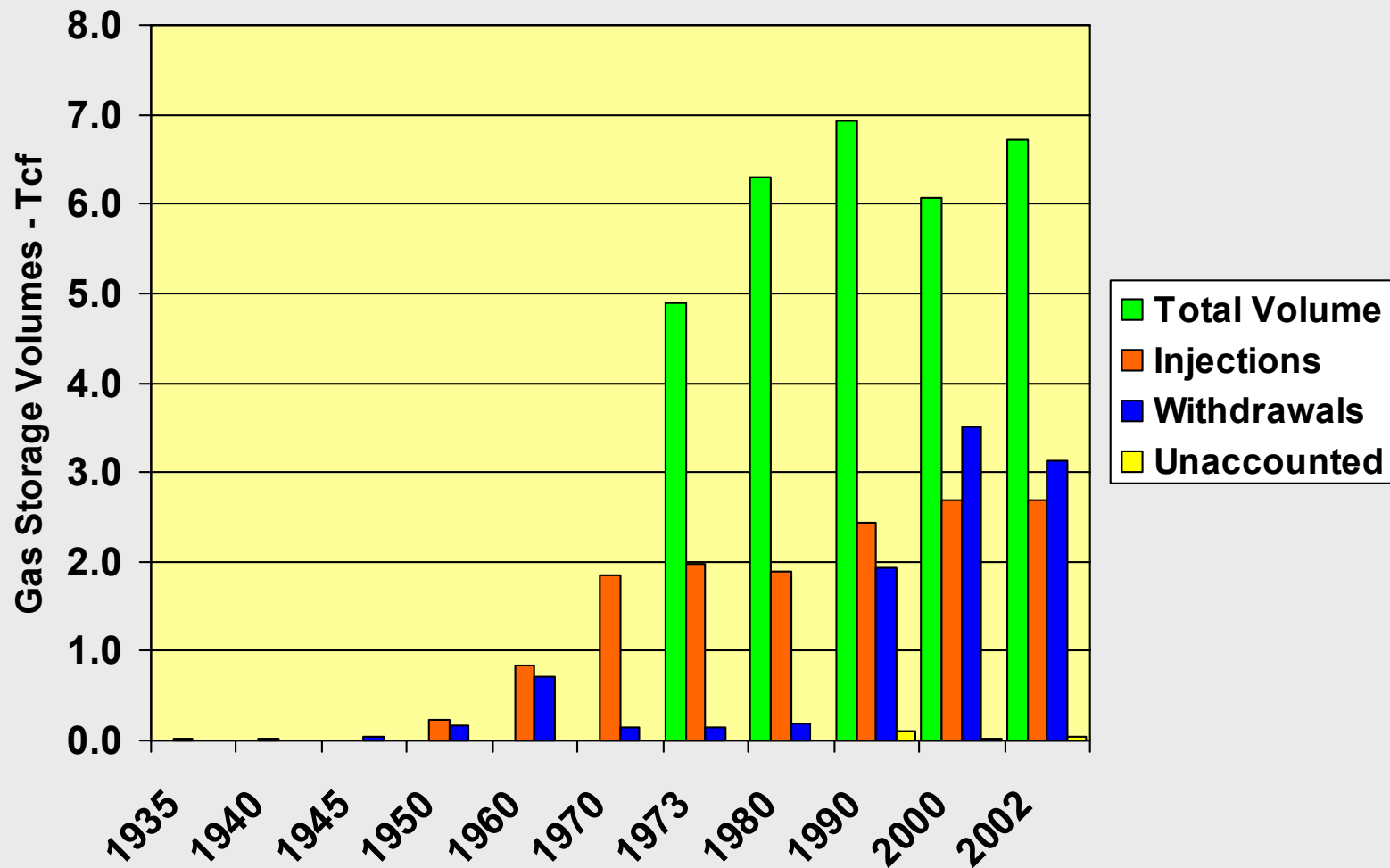
# 24 Gas Storage Technologies With Application to CO<sub>2</sub> Sequestration

| Inventory Verification              | Gas Storage Monitoring         |
|-------------------------------------|--------------------------------|
| Pressure-Volume Techniques          | Surface/Vegetation Monitoring  |
| Reservoir Simulation                | Shallow Water Well Observation |
| Volumetric Gas in Place Calculation | Deep Well Observation          |
| “Watching the Barn Doors”           | Well Logging                   |
| Leak Mitigation Techniques          | Seismic Monitoring             |
| Shallow Gas Recycle                 | Gas Metering                   |
| Aquifer Pressure Control            | Gas Sampling/Analysis          |
| Caprock Sealing                     | Tracer Surveys                 |
| Caprock Integrity Testing           | Production Testing             |
| Geologic Assessment                 | Remote Sensing                 |
| Threshold Pressure                  | Other Technologies             |
| Pump Testing                        | Wellbore Damage Mechanisms     |
| Flow/Shut-In Tests                  | Over Pressuring                |
| Air/CO <sub>2</sub> Injection       |                                |

# Study Conclusion

- > **Gas Storage Industry History**
  - 600 Gas Storage Fields Operated
  - Over 90 Years of History
  - 5 Reported Geologic Gas Migration Incidents
  
- > ***Evidence is Provided That Gas Can Be Safely Stored***

# Volumes of Storage Gas Handled - Tcf



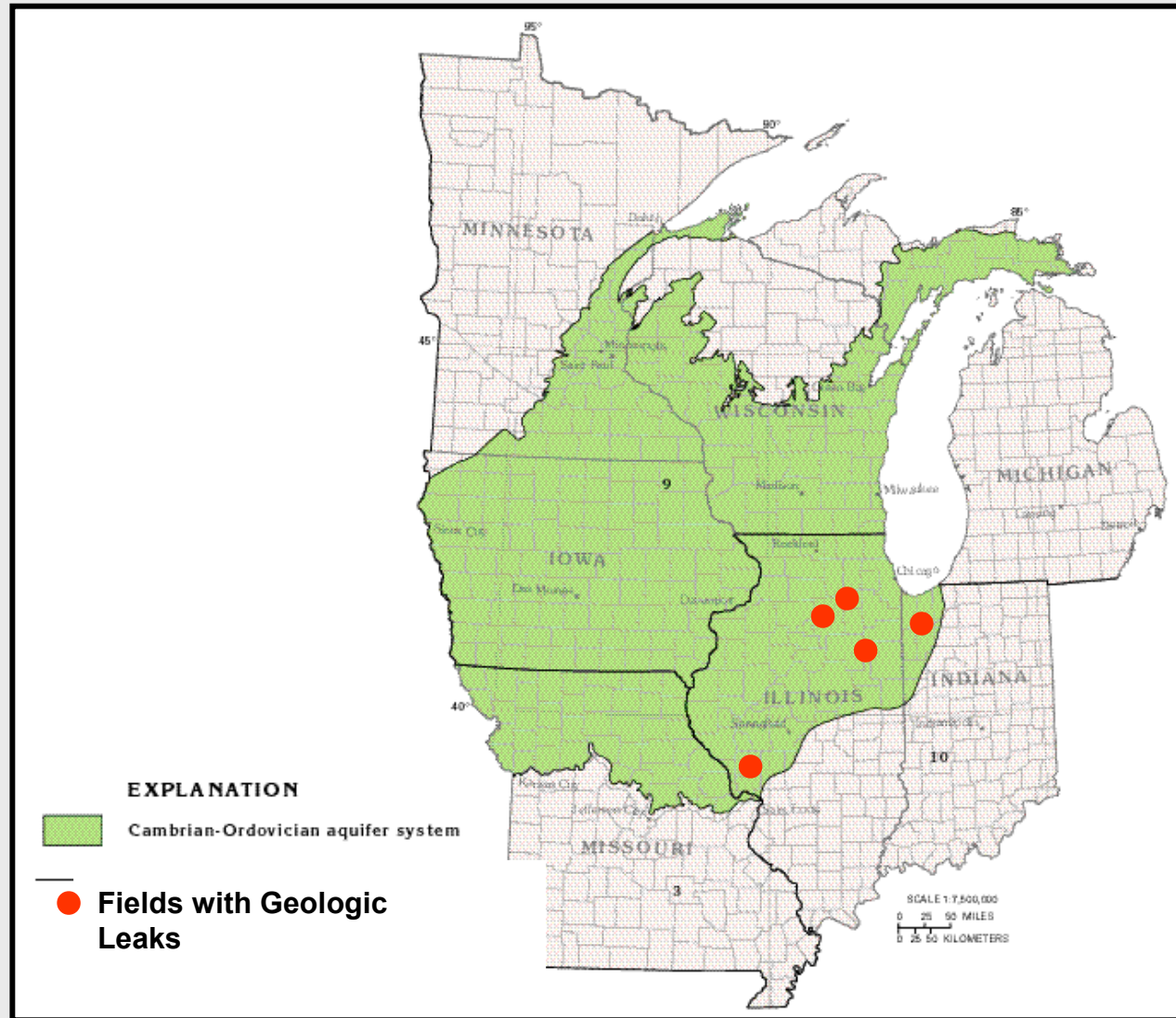
# Study Conclusion

- > **The CO<sub>2</sub> Industry Should Heed the Caution Directed at the Gas Storage Industry During its Infancy:**
  - *“Caution must be exercised in claiming that gas will never be found outside the intended area”*

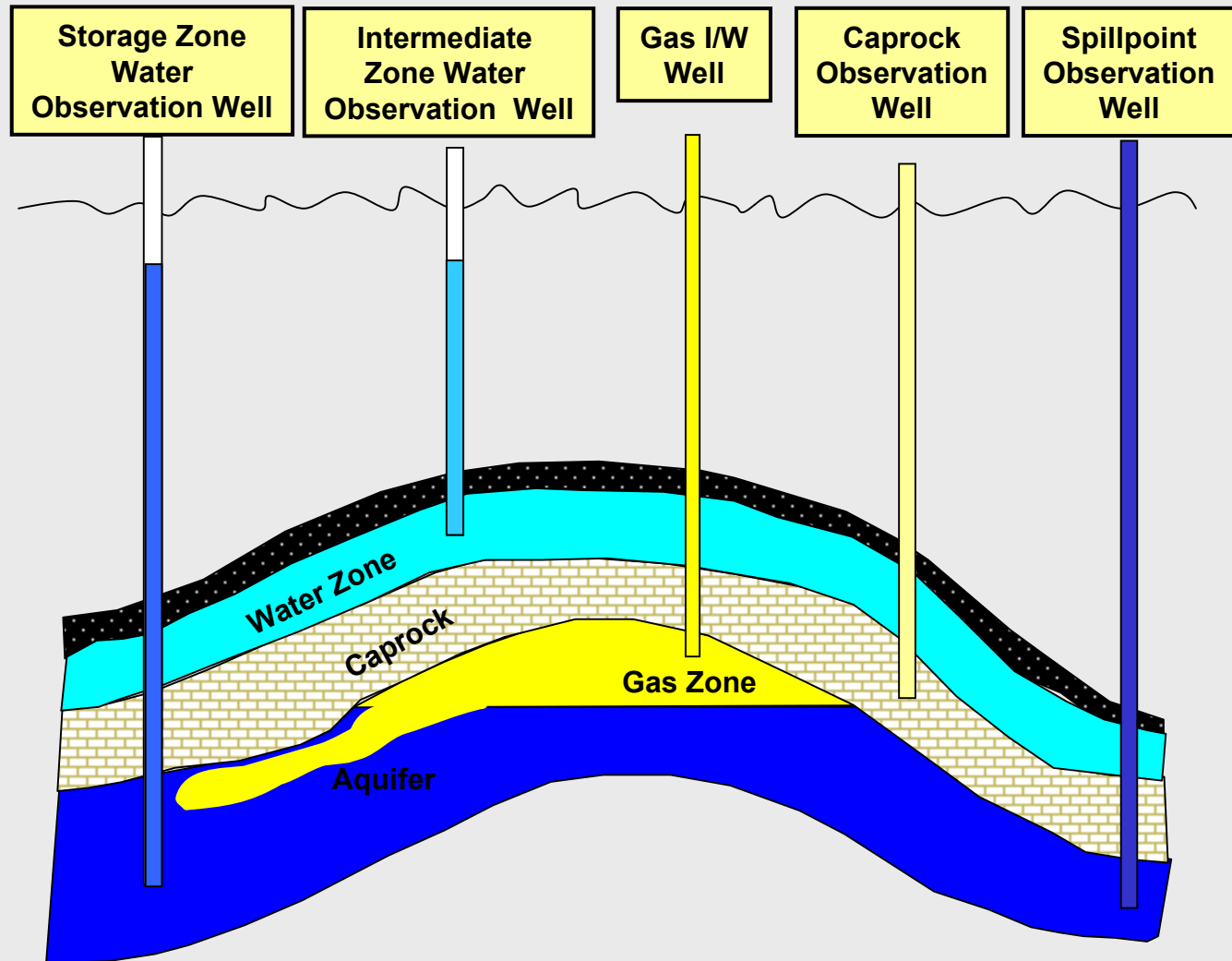
# Gas Storage Fields With Some Type of Leak

| Field Type & Location                 | Type of Leak            | Remedial Action Taken    |
|---------------------------------------|-------------------------|--------------------------|
| Aquifer – Midwest U.S.                | Caprock                 | Aquifer Pressure Control |
| Aquifer – Midwest U.S.                | Caprock                 | Shallow Gas Recycle      |
| Aquifer – Midwest U.S.                | Caprock                 | Field Abandoned          |
| Aquifer – Midwest U.S.                | Caprock                 | Field Abandoned          |
| Aquifer – Indiana, U.S.               | Reservoir Too Shallow   | Abandon Field            |
| Aquifer Storage – Wyoming U.S.        | Wellbore Leak           | Wellbore Remediation     |
| Salt Cavern – Kansas, U.S.            | Wellbore Leak           | Wellbore Remediation     |
| Depleted Gas Field, Canada            | Wellbore Leak           | Wellbore Remediation     |
| Depleted Gas Field, W. Virginia, U.S. | Casing Leaks            | Wellbore Remediation     |
| Depleted Field, California, U.S.      | Improperly Plugged Well | Re-Plug Old Well         |

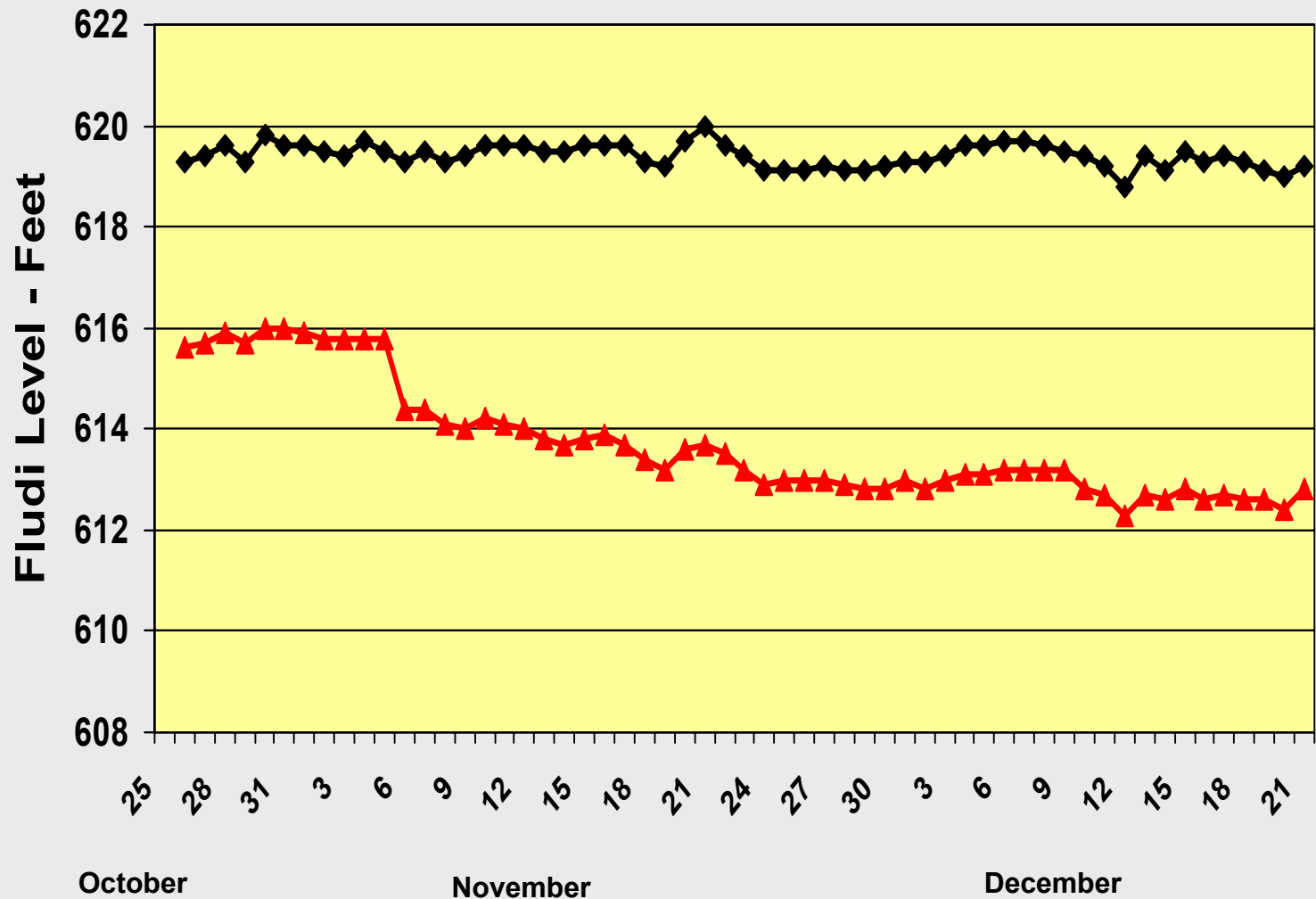
# Mt. Simon Aquifer



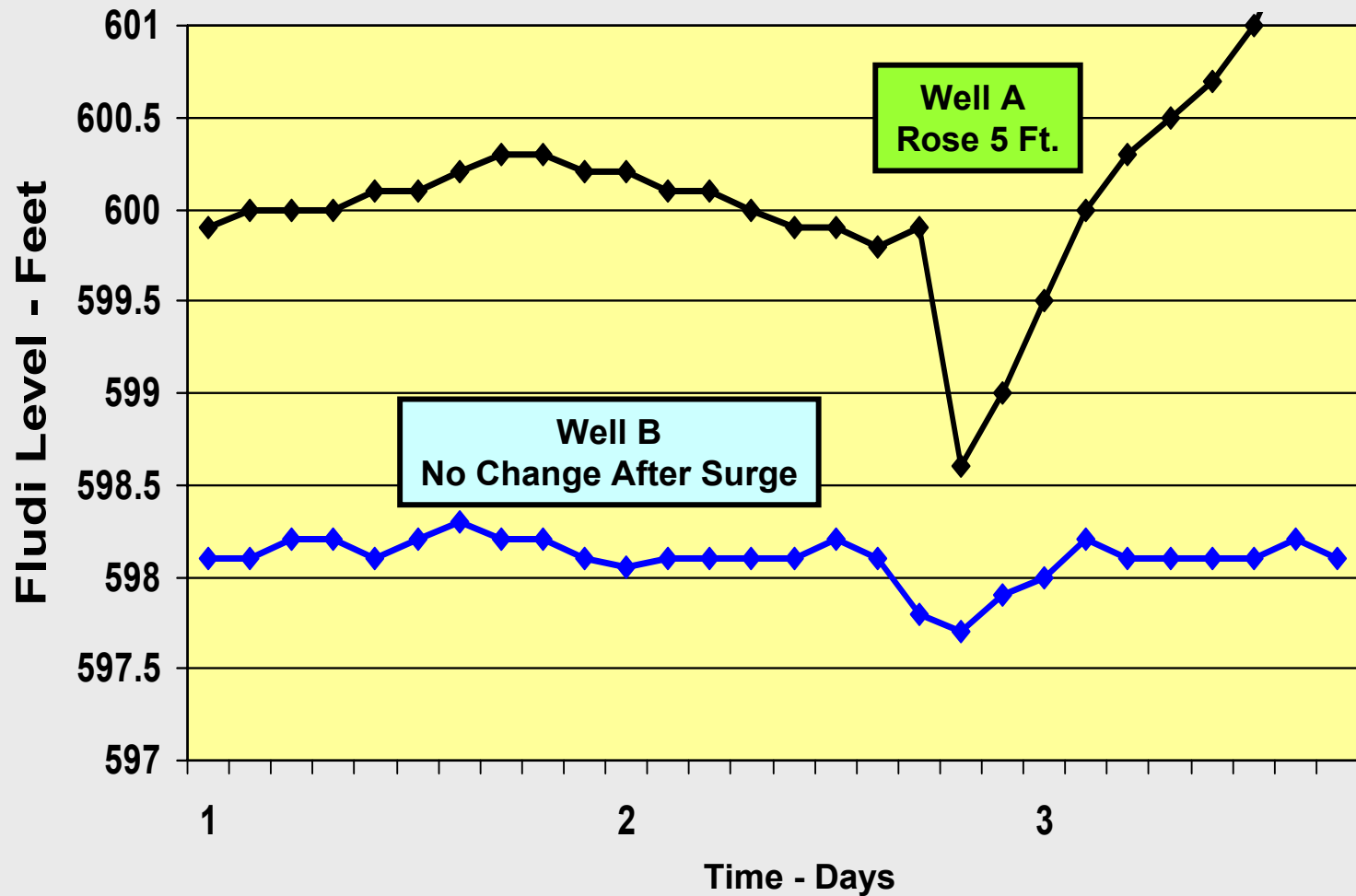
## ***Conclusion:*** Observation Wells are the Best “Early Warning Signal” for Leak Detection



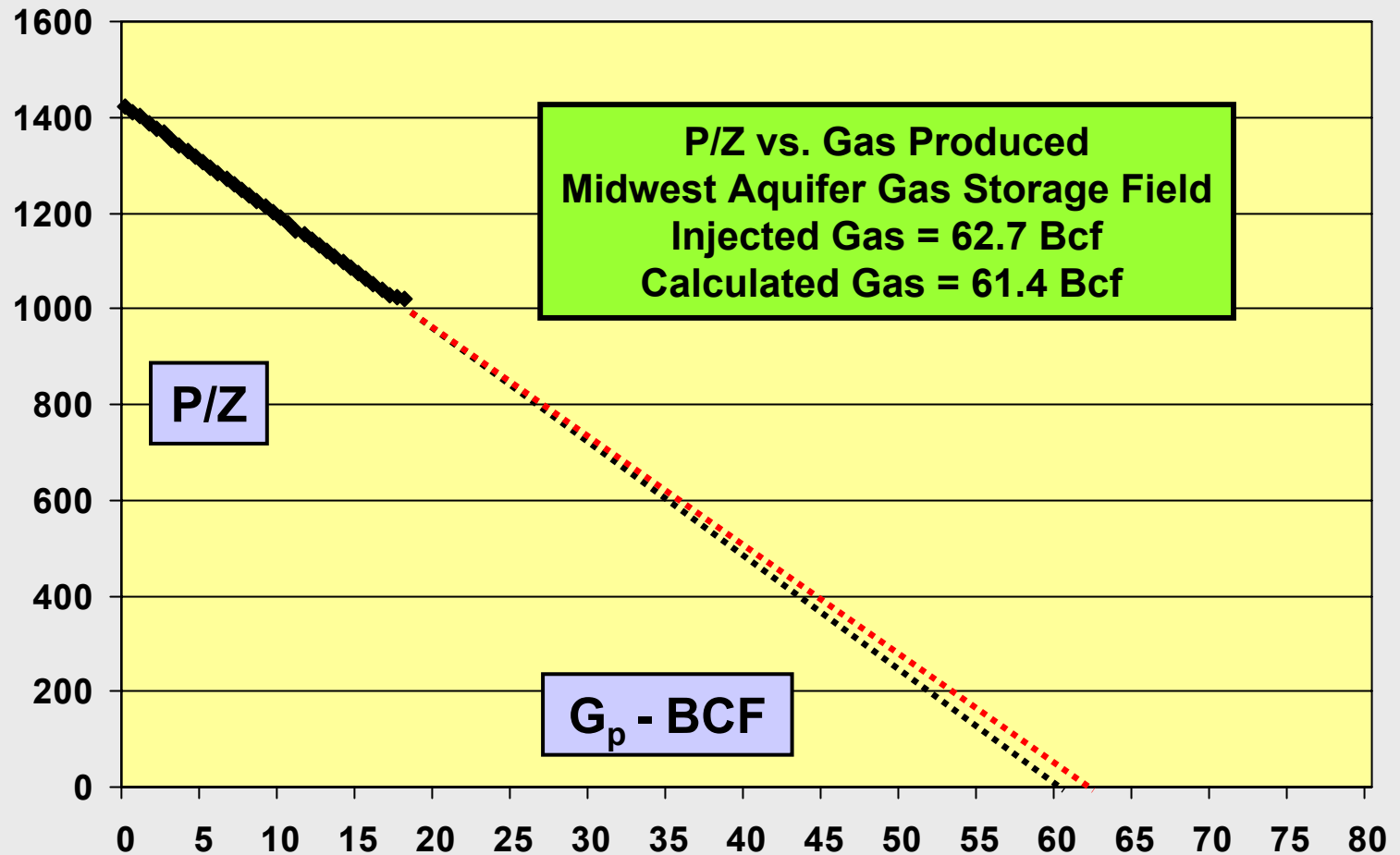
# Observation Well Data



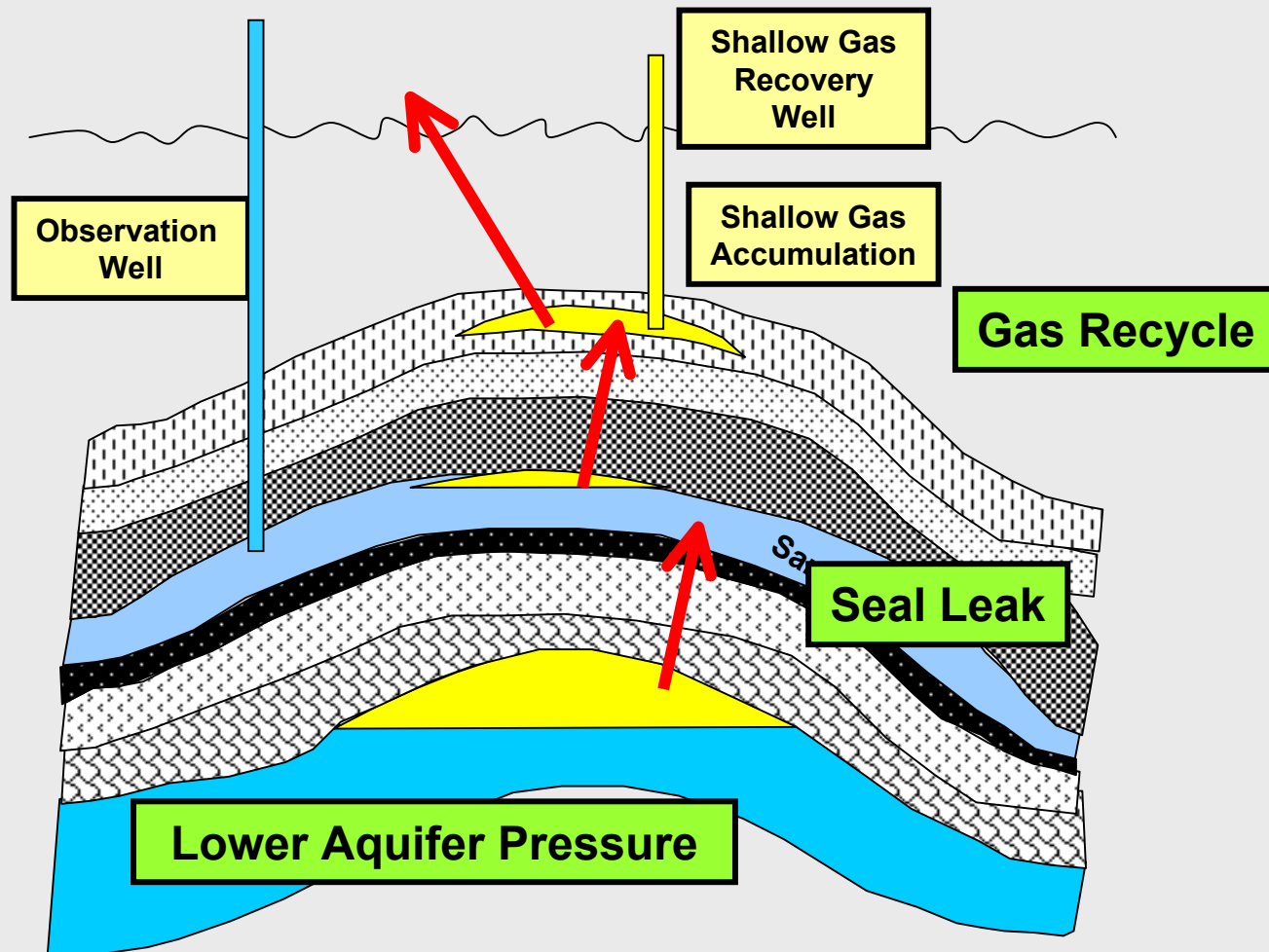
# Observation Well Sensitivity



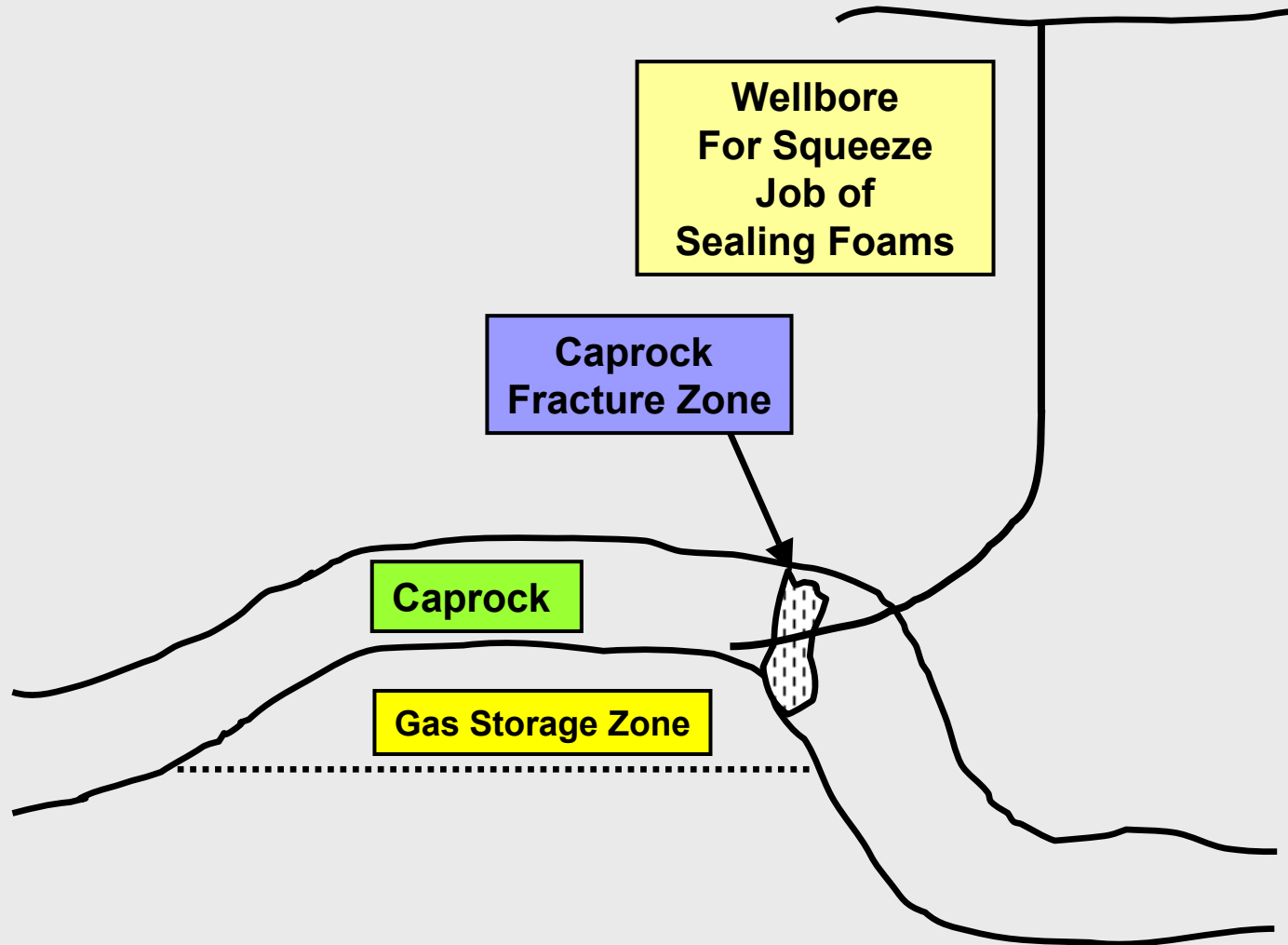
# Pressure Volume Techniques For Inventory Verification



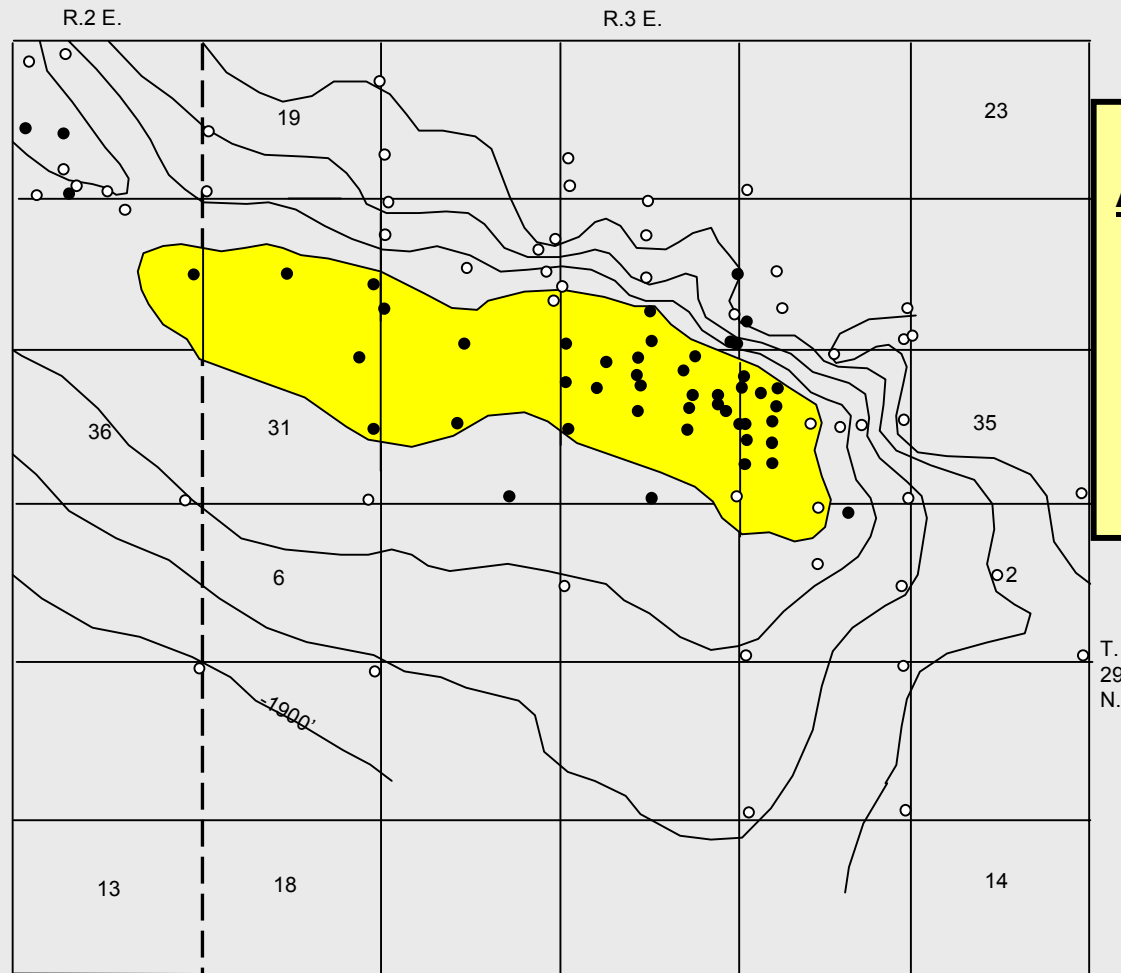
**Conclusion: Leak Control Technology Exists For Gas Storage Reservoirs But is Not Practical for CO<sub>2</sub> Sequestration**



# Caprock Leak Sealing



## ***Study Conclusion: Geologic Leaks are Strongly Related to Gas Storage Structural Closure Requirements***



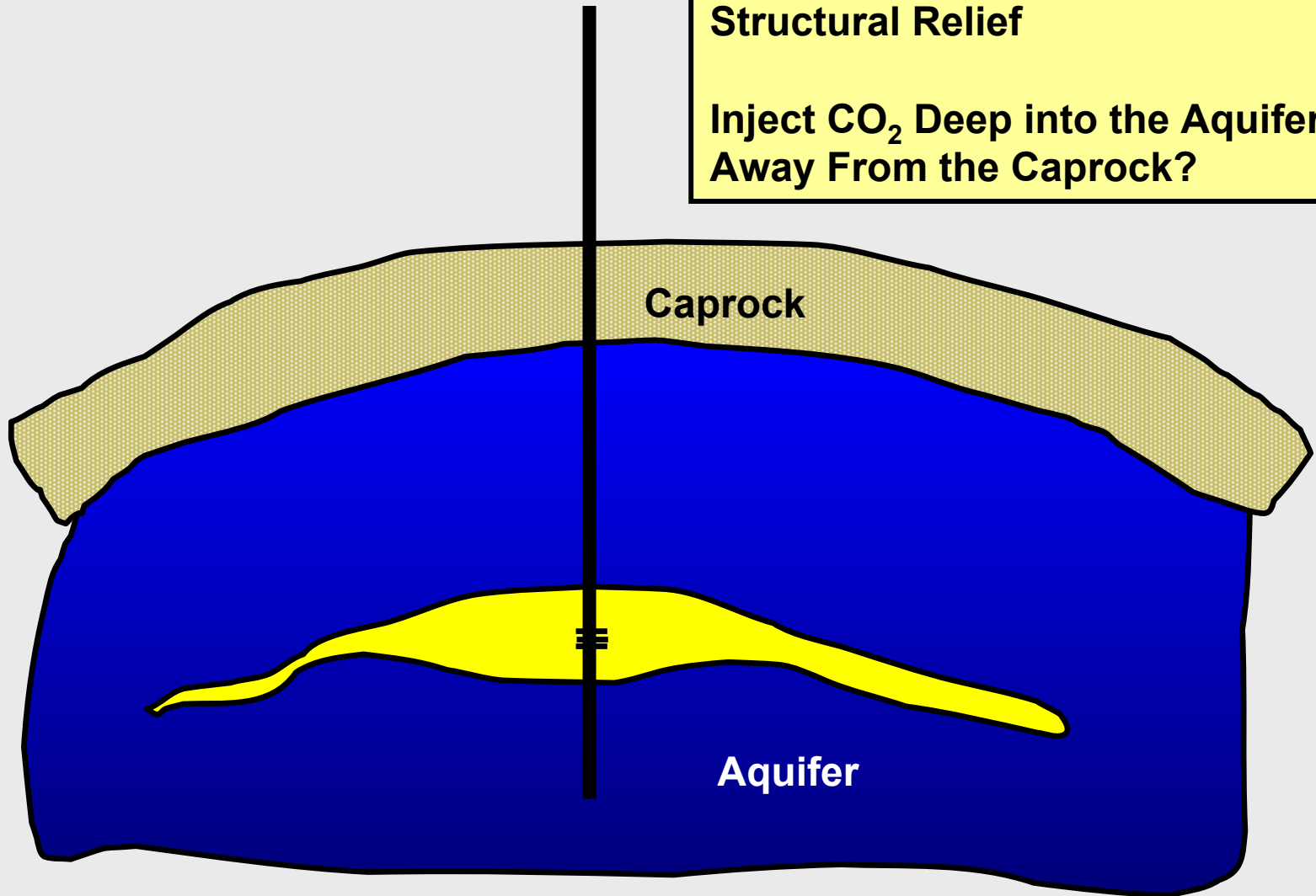
### **Midwest U.S. Aquifer Gas Storage Field**

- Caprock Leak
- Steep NE Flank is Area Of Suspected Leak Due To Steep Flank

# Caprock Leak - Risk Mitigation

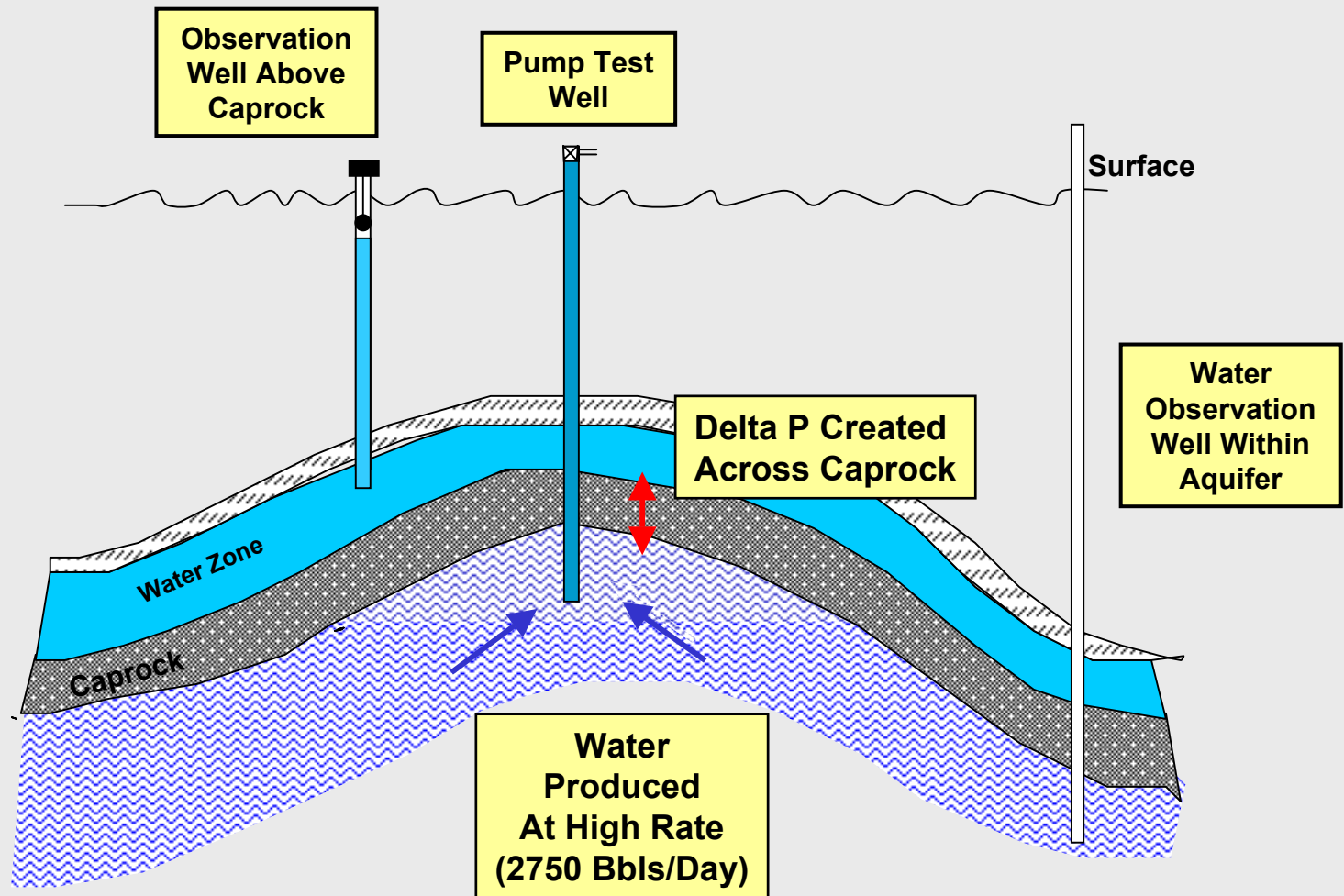
Store in Areas With Minimal  
Structural Relief

Inject CO<sub>2</sub> Deep into the Aquifer  
Away From the Caprock?

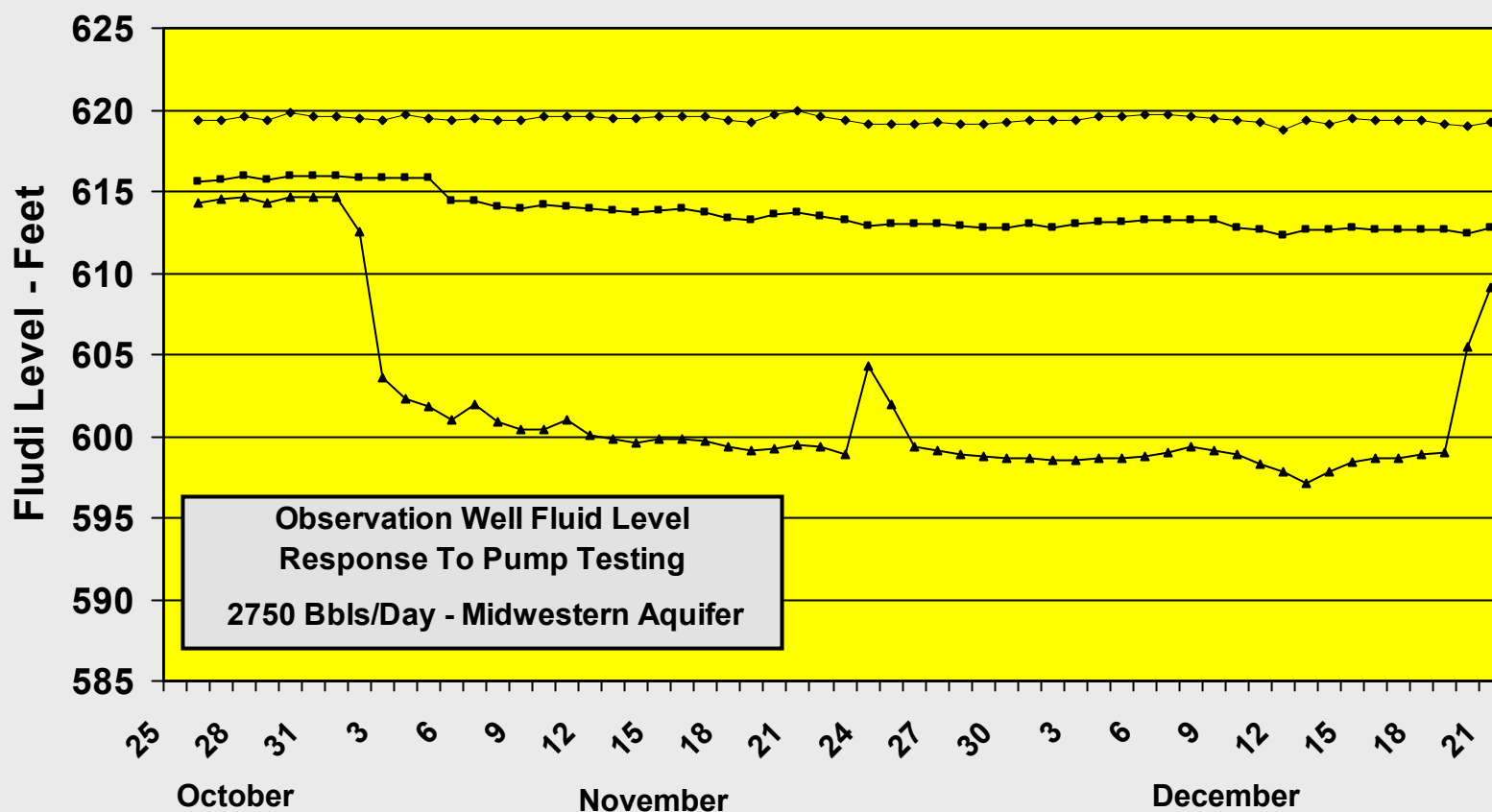


## Conclusion: Gas Storage Industry “Pump Test”

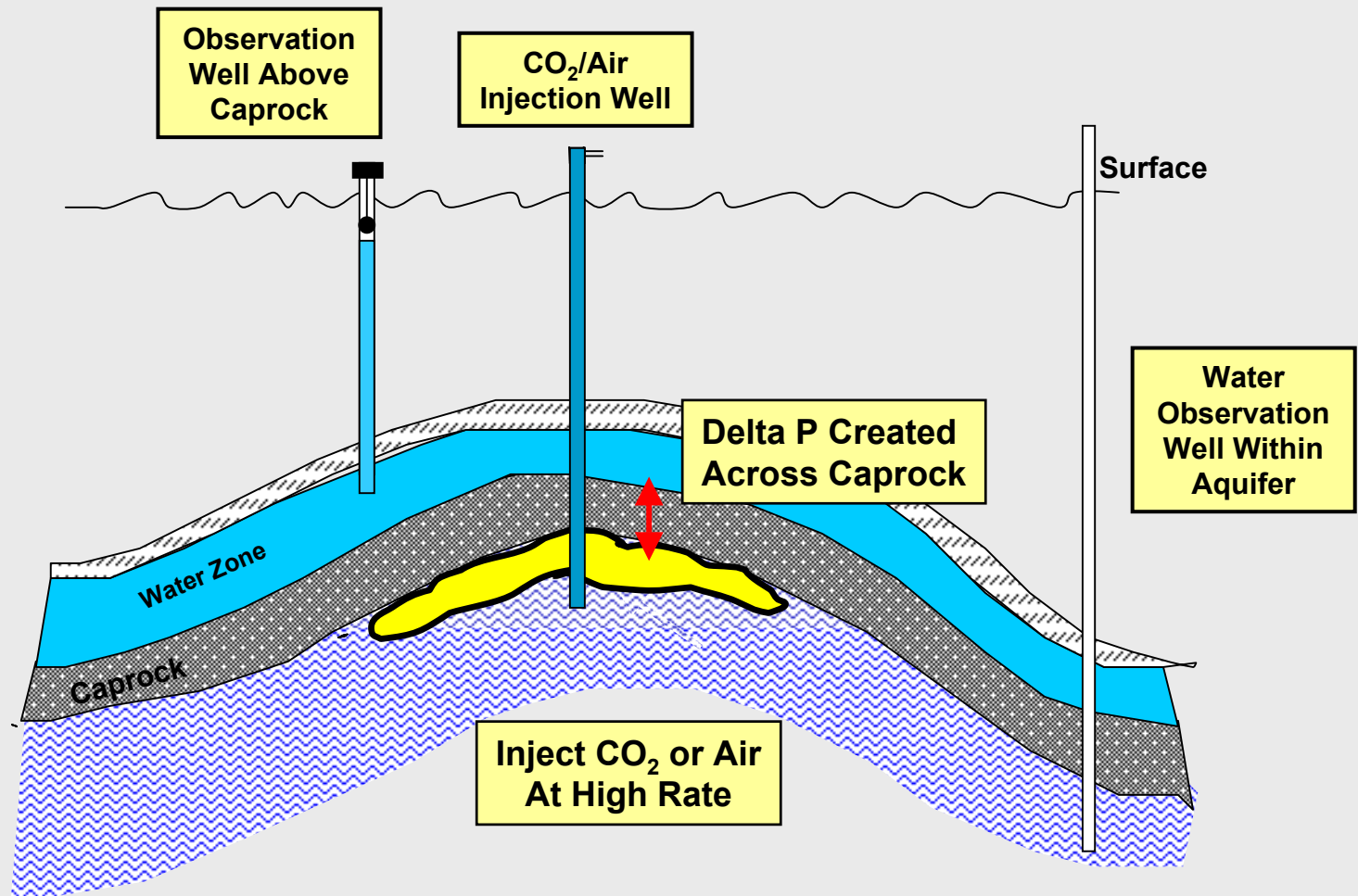
### Procedures Have Potential For CO<sub>2</sub> Field Integrity Testing



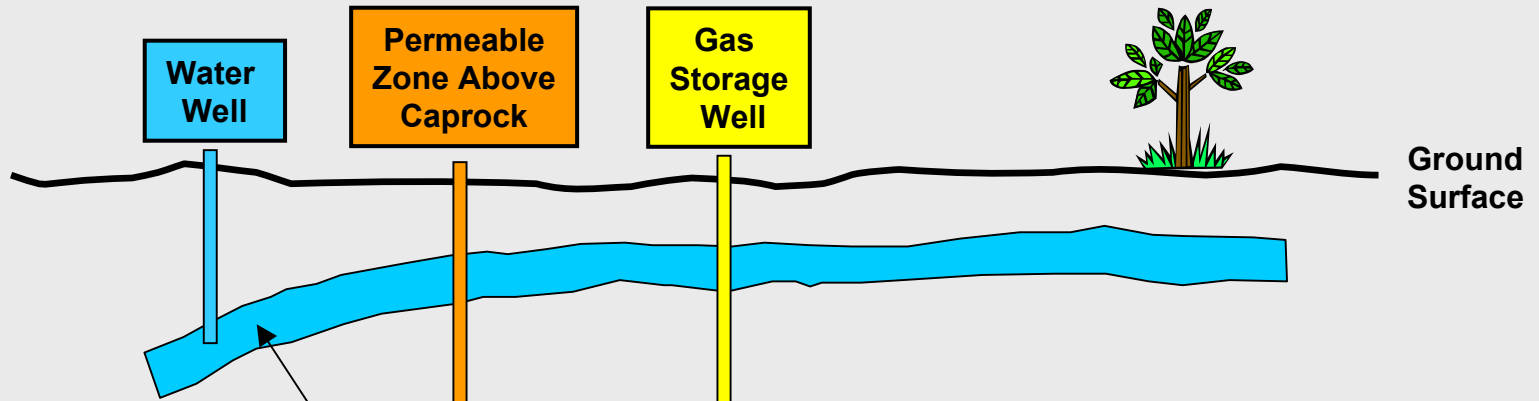
# Observation Well Data During Pump Test Mt.Simon Aquifer Midwestern U.S.



# Custom “Pump Test” For Caprock Integrity For CO<sub>2</sub> Sequestration



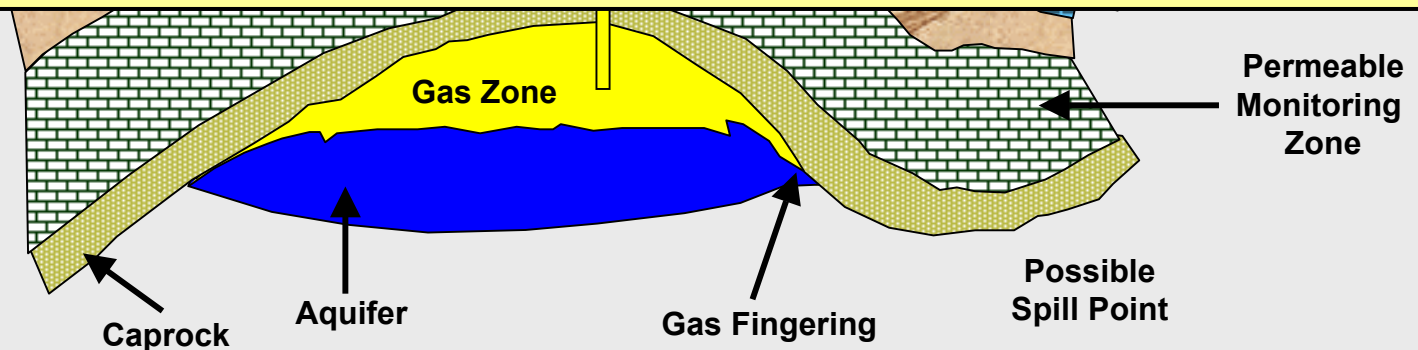
# Monitoring of CO<sub>2</sub> Requires a Combination of (Available) Techniques Observation Wells, Pressure-Volume Studies,



## "Watching The Barn Doors"

**"If one meters gas into and out of the reservoir, and makes all necessary observations to assure no gas other than production gas has left the gas reservoir, one is assured that the inventory is there".**

*D.L. Katz, 1968*



# Summary and Recommendations

- > Safe Storage Has Been Demonstrated**
- > Valuable Storage Techniques and Procedures Exist and Are Applicable to Geologic CO<sub>2</sub> Sequestration**
- > Areas For Further Research By the CO<sub>2</sub> Sequestration Industry Include:**
  - Observation Well Response**
  - Pump Testing Procedures Specific To CO<sub>2</sub> Sequestration**
  - Technology Integration for Locating and Sealing Geologic Leaks**
  - Field Integration and Field Testing**